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might be accidental, just as Castle's non-linear results so obtained were accidental. The fact that the order really turns out to be hairy magenta forked illustrates the latter point to a nicety and falls in line with the other results to show the fallacy of the method of combining separate experiments for a determination of the nature of linkage.

[8] It is of course possible that larger counts would give double crossovers in these cases. But this is very improbable in the case of hairy, magenta, and forked, because of the shortness of the distance involved; and even in the case of yellow, crossveinless, and vesiculated, where the distance is longer, there could scarcely be enough double crossing over to throw the factors much out of line.

[9] The sterility of rugose-glazed hybrids was first observed by Metz, who attributed it to "incompatibility," because he thought that glazed females were fertile. He had noticed their sterility when mated to rugose males, but he termed this also "incompatibility," as he believed that glazed females were not sterile when mated to glazed or to wild-type males. Now that it is known that glazed females are almost always sterile, it is obvious that the failure of the hybrids to produce offspring is due to the dominance of the sterility of glazed. In my work, each class of females (glazed, wax, and hybrids) was tested with four kinds of males (wild-type, rugose, glazed, and wax); and in all cases, with the exceptions already noted, the matings produced no offspring, though all four types of males are otherwise fertile. Metz has, consequently, withdrawn his "incompatibility" theory and accepted the interpretation given above.

[10] Muller, H. J., *Amer. Nat.*, **50,** 1916 (193–221, 284–305, 350–366, 421–434).

[11] Gowen, J. W., *Genetics,* **4,** 1919 (205–250).

[12] Bridges, C. B., *Genetics,* **2,** 1917 (445–465); *J. Gen. Physiol.*, **1,** 1919 (645–656).

[13] The yellow genes in mice and rats suggest themselves in this connection; but there is no proof that the yellow mouse case is actually like the hypothetical vermilion vermilion-deficiency combination described above, or that yellow in mice is homologous with either of the yellow factors in rats.

[14] Muller, H. J., *Amer. Nat.*, **48,** 1914 (508–512).

[15] Altenburg, E., and Muller, H. J., *Genetics,* **3,** 1920 (1–59); Bridges, C. B., and Mohr, O. L., *Genetics,* **4,** 1919 (283–306).

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# *THE INTENSITIES OF X-RAYS OF THE L-SERIES, III. CRITICAL POTENTIALS OF THE PLATINUM AND TUNGSTEN LINES*

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This work is a continuation of that of Webster and Clark[1] and Webster.[2] The methods used by them are applied to the classification of some lines that were doubtful, and the general validity of the intensity laws is tested by the use of a different metal as anticathode (tungsten).

*Apparatus.*—The high tension outfit constructed at the Massachusetts Institute of Technology by Prof. D. L. Webster and described in these PROCEEDINGS[3] was used without essential modification. The Chaffee voltmeter was calibrated by measuring the current through a megohm resistance in parallel with it, and also checked by measurement of the high frequency limit of the spectrum.

The spectroscopic arrangement consisted of a large calcite crystal with a face $5^1/_2 \times 8$ cm., with a wide slit (1 cm.) placed close to the crystal and the plate about 70 cm. from the crystal. The anticathode was about 20 cm. from the crystal. With this simple setup a greater resolving power and dispersion was obtained than with the mica spectrograph used by Prof. Webster. Irregularities in the crystal gave little trouble. To exclude stray radiation the plate holder was placed in a lead box extending nearly to the crystal. In this way a considerable region of the spectrum can be mapped at once without moving the crystal; the range from 0.900 Å to 1.24 Å in the platinum spectrum, for instance, being spread over about 4 cm.

No attempt was made to measure wave-lengths directly, but for new lines the values could be found to about 0.3% by intperolation on the plate. Tubes with platinum and tungsten anticathodes and thin glass windows were kindly furnished by the General Electric Co. The former contained no iridium, but high voltage pictures showed a faint tungsten spectrum.

*L-Series of Platinum and Tungsten.*—The platinum and tungsten L-series, containing all lines observed with certainty here, is shown in Fig. 1. Reproductions of photographs of the region from $\gamma_4$ to $\beta_4$ are shown in Fig. 2, *a* and *b*. The tungsten spectrum has received special attention, and Dershem,[4] Overn,[5] de Broglie[6] and Siegbahn[7] have reported a large number of faint lines. All of those recorded by Siegbahn have been found, but two of the faint ones recorded by Overn only have not been observed.

In platinum, besides the 13 lines that have been followed through from element to element, we find two more lines. $\beta_6$ and $\gamma_5$, of which the wave-lengths as interpolated are 1.080 and 0.988, respectively. $\beta_6$ has been observed by Webster, while $\gamma_5$ has apparently escaped attention so far. That these two lines are really part of the platinum L-series is supported by the fact that lines occur in corresponding positions in tungsten. Thus the wave-length interval from $\gamma_5$ to $\gamma_1$, in tungsten is approximately the same as in platinum, and the same is true of the interval from $\beta_6$ to $\beta_5$.

There seems to be a real difference between the tungsten and platinum spectra as observed here. With pictures taken under similar conditions in the two elements, the relative intensity of the lines is not always the same, and some lines occur in tungsten which are apparently absent in platinum. Thus $\beta_7$, $\beta_8$, and $\beta_9$ and $\gamma_7$ which appear in tungsten are not found at all in platinum. For intensity differences, $\beta_5$ is much stronger than $\beta_6$ in platinum, but they are of about the same intensity in tungsten. There is also a change with $\gamma_2$, which is stronger than $\gamma_3$ in platinum, but weaker than $\gamma_3$ in tungsten. In the case of both $\beta_5$ and $\gamma_2$ we are dealing with lines which lie near the absorption limits, and as there is some evidence to show a progressive shift from element to element of the absorption limits relative to $\beta_5$ and $\gamma_2$ which would bring the absorption limits on opposite sides of these two lines in platinum and tungsten, this may account for the difference in intensity here.

Another difference in intensity occurs in the case of $\beta_4$, which is stronger in platinum than it is in tungsten, but we can ascribe it to a different cause. Noticing that $\beta_7$ which is between $\beta_1$ and $\beta_4$ in tungsten is apparently absent in platinum, and that if $\beta_4$ and $\beta_7$ in tungsten were to stay at a constant wave-length interval from $\beta_3$ and $\beta_2$ respectively, they would nearly coincide in platinum, we can think of $\beta_4$ as in reality composed of these two lines. Since $\beta_3$ and $\beta_4$ belong together in $L_3$ and $\beta_2$ and $\beta_7$ in $L_1$, we would expect this wave-length interval to remain constant.

Wave-lengths of the tungsten and platinum lines in the L-series are given in table I. Siegbahn calls the line at 1.2031 $\beta_5$ but this puts it out of line with $\beta_5$ in other elements. The wave-length interval from $\beta_2$ to $\beta_5$ is quite constant from element to element, and if it is not to be far off here, we would have to take the line at 1.2118 Å as $\beta_5$.

TABLE I

| LINE | PLATINUM | TUNGSTEN | LINE | PLATINUM | TUNGSTEN |
|---|---|---|---|---|---|
| $l$............. | 1.499 | 1.67505 | $\eta$............... | 1.242 | 1.4177 |
| $\alpha_1$............ | 1.313 | 1.47348 | $\gamma_1$.............. | 0.958 | 1.09553 |
| $\alpha_2$............ | 1.323 | 1.48452 | $\gamma_2$.............. | 0.933 | 1.06584 |
| $\beta_1$............ | 1.120 | 1.27917 | $\gamma_3$.............. | 0.929 | 1.05965 |
| $\beta_2$............ | 1.101 | 1.24191 | $\gamma_4$.............. | 0.900 | 1.02647 |
| $\beta_3$............ | 1.098 | 1.26000 | $\gamma_5$.............. | 0.988 | 1.1284 |
| $\beta_4$............ | 1.142 | 1.29874 | $\gamma_6$.............. | ..... | 1.079* |
| $\beta_5$............ | 1.072 | 1.2031 | $\gamma_7$.............. | ..... | 1.072 |
| $\beta_6$............ | 1.080 | 1.2118 | $\gamma_8$.............. | ..... | 1.044* |
| $\beta_7$............ | ..... | 1.2871 | | | |
| $\beta_8$............ | ..... | 1.2205 | | | |
| $\beta_9$............ | ..... | 1.202 | | | |

*Observed by Overn only.

*Assignment of the Lines to Sub-Series.*—The existence in platinum of the three series $L_1$, $L_2$, and $L_3$ with critical potentials near the quantum potentials of $\beta_5$, $\gamma_2$ and $\gamma_4$ respectively was shown by Webster and Clark[1] and Webster.[2] The stronger lines were measured directly by ionization methods, and the weaker ones were classified by means of constant voltage photographs. The following lines have been definitely assigned, by measurements on platinum alone:

$L_1$ $l$, $\alpha_2$, $\alpha_1$, $\beta_2$, $\beta_6$, $\beta_5$
$L_2$ $\eta$, $\beta_2$, $\gamma_1$
$L_3$ $\gamma_4$

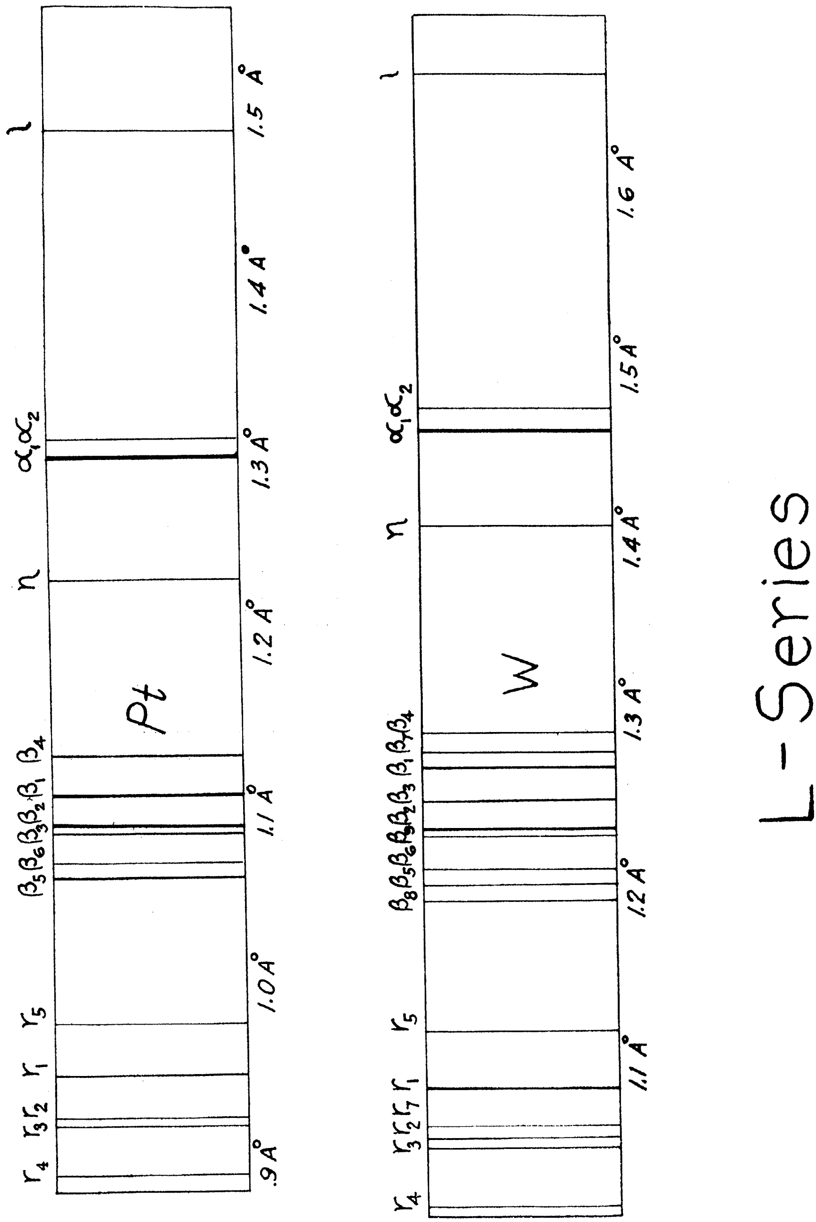
L-Series
Pt
W
l
α₁ α₂
η
β₅ β₆ β₃ β₂ β₁ β₄
β₈ β₅ β₆ β₂ β₃ β₁ β₇ β₄
γ₅
γ₁
γ₃ γ₂
γ₃ γ₂ γ₇ γ₁
γ₄
1.5 Å
1.4 Å
1.3 Å
1.2 Å
1.1 Å
1.0 Å
.9 Å
1.6 Å
1.5 Å
1.4 Å
1.3 Å
1.2 Å
1.1 Å

FIG. 1

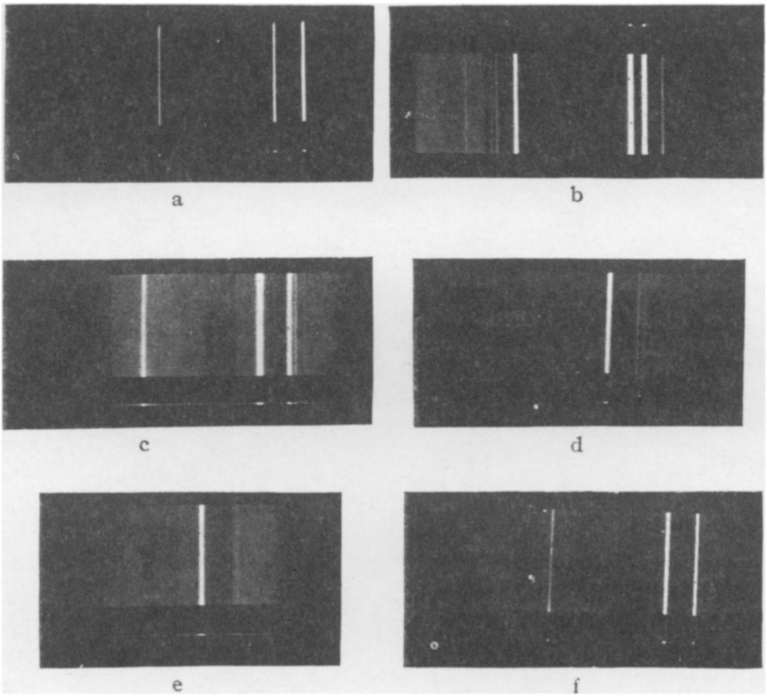

FIG. 2

In the present work these results have been confirmed. This leaves as still doubtful in platinum $\gamma_2$, $\gamma_3$, $\gamma_5$, $\beta_4$ and $\beta_3$. Of these still unclassified lines, $\gamma_2$ and $\gamma_3$ are so faint that although well resolved in all pictures, the results are still uncertain. The possibility of a fourth critical potential, as might be indicated by Sommerfeld's theory, makes these lines particularly interesting. $\gamma_5$ is too weak to show except at high voltages, with any degree of certainty. For all of these very weak lines it will be necessary to cut down the general radiation by using greater dispersion (plate farther from crystal) than is at present possible without unduly weakening the lines themselves by absorption in the air. For this purpose a vacuum spectrograph is now under construction.

$\beta_3$ is so close to $\beta_2$ in platinum as to make work on this line very difficult, but in tungsten it lies midway between $\beta_1$ and $\beta_2$. With the platinum anticathode used, where the tungsten lines also showed, the coincidence of W $\gamma_1$ with Pt $\beta_3$ was another complication, so that results were obtained on this line only in tungsten.

Pt $\beta_4$ has given rather anomalous results. Webster and Clark's[1] ionization curves showed a critical potential near $V_2$, but the uncertainty here was greater than with the stronger lines. In Webster's[2] photographs, however, it showed well below $V_2$, but the presence of a line here could be ascribed to the near coincidence of Ir $\beta_2$ with Pt $\beta_4$. With the present anticathode there were no iridium lines, and yet $\beta_4$ showed below $V_2$. We can account for this if we regard it as the combined line $\beta_4$ and $\beta_7$. The work with tungsten showed $\beta_7$ to be $L_1$ and $\beta_4$ to be $L_3$, so that the part showing below $V_2$ is simply $\beta_7$. That the ionization work indicated a critical potential the same as that of $\beta_1$ can only be ascribed to the uncertainty of the measurements on a line as weak as $\beta_4$ and to the disturbing effect of $\beta_7$, which would tend to decrease the apparent critical potential.

The results on tungsten are well illustrated by the reproductions in Fig. 2, *c*, *d*, *e*, and *f*. In *c*, *d*, and *e*, the product of current through the tube, time of exposure, and square of the voltage was made the same in all three. In *f* the time of exposure was shorter. The critical potentials calculated for tungsten would be:

$V_1$ 10.2 kilovolts [Quantum potential of $\beta_5$]
$V_2$ 11.6 kilovolts [Quantum potential of $\gamma_2$]
$V_3$ 12.0 kilovolts [Quantum potential of $\gamma_4$]

These constant voltage pictures show us how $\beta_4$ and $\beta_7$ are to be classified. In *f* at 13 kv. we have them showing at nearly equal intensities. At 12.5 kv. $\beta_4$ is noticeably weaker, and at 12 kv. ($V_3$) $\beta_4$ is out completely, assigning it to $L_3$, while $\beta_7$ is still strong. At 11.5 kv., below $V_2$, $\beta_7$ still shows, although faint, assigning it to $L_1$.

That $\beta_5$ and $\beta_6$ belong together in $L_1$ is shown by the fact that they show with constant intensity ratio down to $11^1/_2$ kv.

$\beta_3$ disappears at 12 kv. placing it in $L_3$.

The evidence in these pictures would seem to put $\gamma_2$, $\gamma_3$ and $\gamma_5$ in $L_3$, as they show well at 12.5 kv., but are out at 12. They are still weaker, however, than $\beta_7$ which is very faint near its critical potential, so it is possible they would not show at 12 kv. even if belonging to $L_2$.

$\beta_8$, $\beta_9$ and $\gamma_7$ are too weak to show except at high voltages.

The behavior of the other lines that have already been classified is what would be expected. The change in intensity ratio of $\beta_1$ and $\beta_2$ is particularly noticeable. They are nearly the same at 13 kv., but quite different at 12. $\gamma_1$ behaves as would be predicted.

In some of the pictures the absorption limit of tungsten, due to absorption in the anticathode, shows near $\beta_5$, and there is also one near $\beta_2$. This latter has exactly the wave-length of Zinc $K\gamma$ and is probably due to zinc in the glass of the tube. The light spot showing in the region between $\gamma_1$ and $\beta_5$ is an imperfection in the crystal.

The classification of the lines, to date, is as given below. Those for which further work is necessary are marked with a question mark.

| | |
|---|---|
| $L_1$ | $l$, $\alpha_2$, $\alpha_1$, $\beta_2$, $\beta_5$, $\beta_7$ |
| $L_2$ | $\eta$, $\beta_1$, $\gamma_1$ |
| $L_3$ | $\beta_3$, $\beta_4$, $\gamma_2$(?), $\gamma_3$(?), $\gamma_5$(?), $\gamma_4$ |

It is to be noted that the photographic method as here employed does not enable us to determine the critical potential of each line independently, as does the ionization method; but only serves to classify lines if we assume they must all fall into three series, whose critical potentials are known. It is hoped to develop a method in which quantitative intensity measurements on the plate can be made. In this way curves similar to ionization-voltage curves can be obtained.

This work has been carried out under the direct supervision of Prof. D. L. Webster, without whose very material aid it would have been impossible.

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[1] Webster, D. L., and Clark, H., these PROCEEDINGS, **3,** 1917 (181–5).

[2] Webster, D. L., *Ibid.*, **6,** 1920 (26).

[3] Webster, D. L., *Ibid.*, **6,** 1920 (269–72).

[4] Dershem, E., *Physic. Rev.*, Ithaca, **11,** 1918 (461–76).

[5] Overn, O. W., *Ibid.*, **13,** 1919 (137–42).

[6] de Broglie, M., *C. R. Paris Acad. Sci.*, **169,** 1919 (962–5).

[7] Siegbahn, M., *Phil. Mag., London,* **38,** 1919 (639).